FE-Simulation of fast switching of magnetic nanoelements

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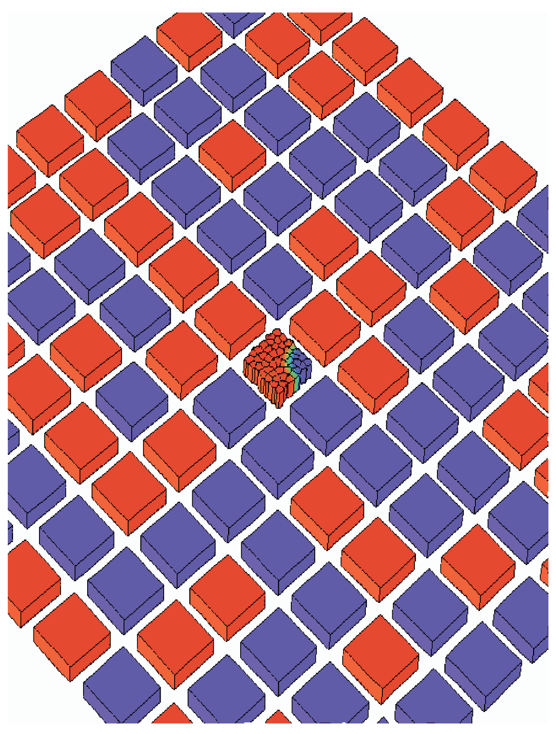
Motivation

Magnetic recording devices (heads and media) must be designed to produce higher output signals and lower noise to achieve higher recording densities. Magnetic switching of small particles and thin films becomes increasingly important. Numerical micromagnetics is an essential tool to optimize magnetic storage media and sensors. The application of these devices requires a profound knowledge of the reversal mechanism. The magnetisation reversal processes are studied using a 3D hybrid finite element/ boundary element micromagnetic model.



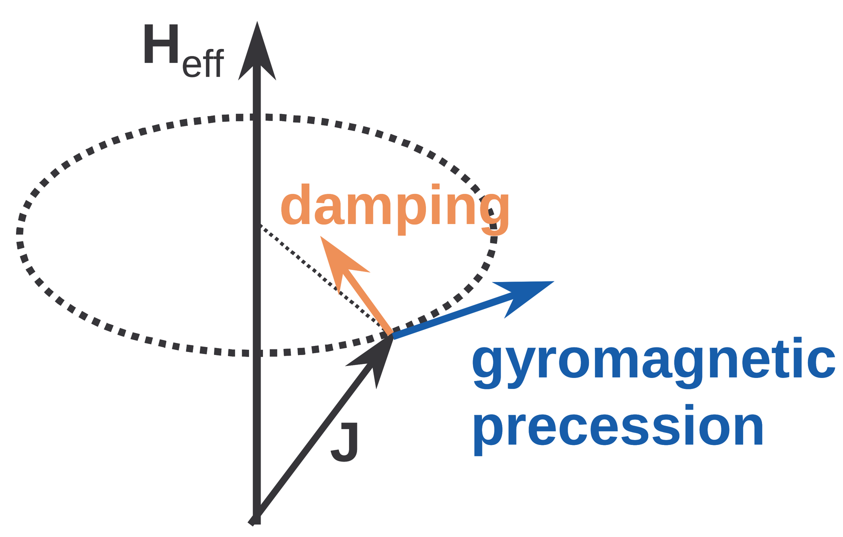
Array of patterned media representing the written state of a hard disk.

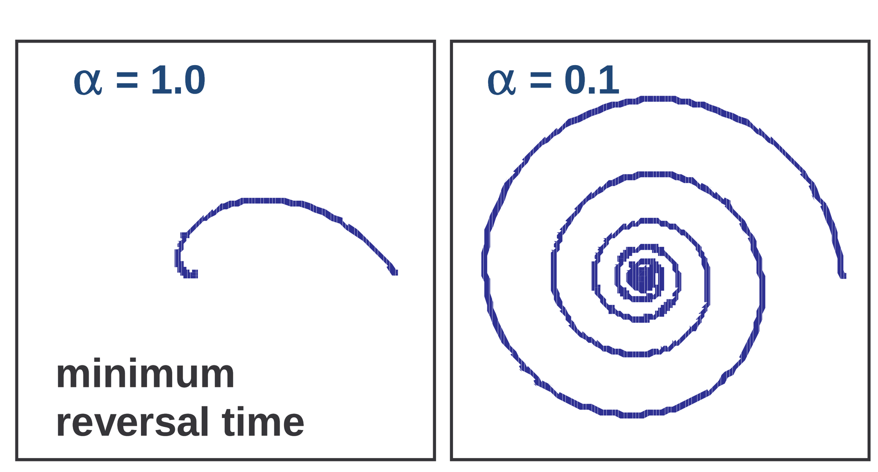
Micromagnetic framework Finite Element model

Precession of magnetisation:

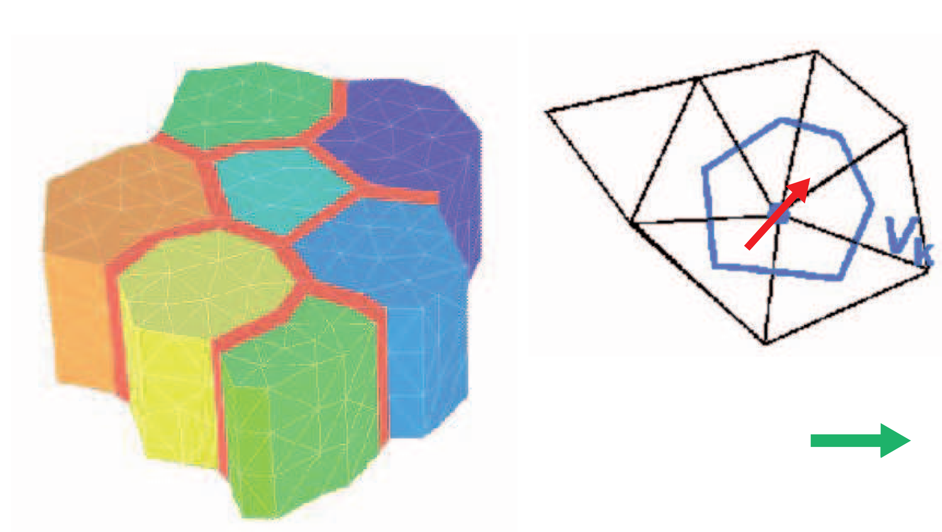
$$\frac{\partial \mathbf{J}}{\partial t} = -|\gamma|\left(\mathbf{J}\times\mathbf{H}_{\mathrm{eff}}\right) + \frac{\alpha}{J_s}\left(\mathbf{J}\times\frac{\partial \mathbf{J}}{\partial t}\right)$$

Landau-Lifshitz-Gilbert equation





Discretization into finite elements:



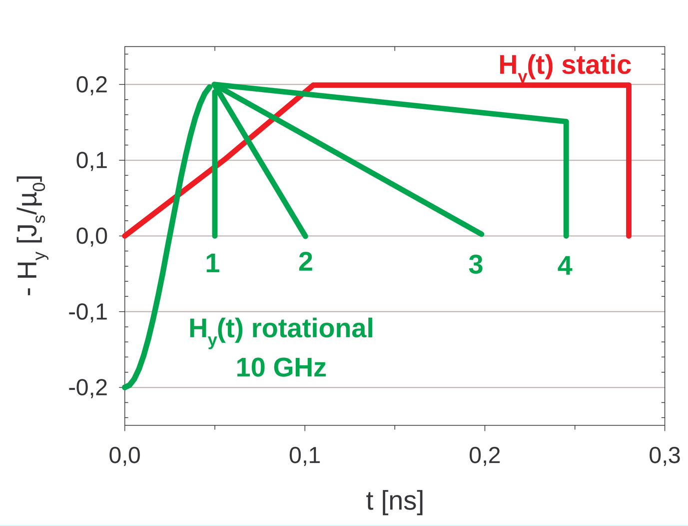
$$\vec{H}_k^{eff} = -\frac{1}{V_k}\frac{\partial E(\vec{J}_1, \vec{J}_2 \ldots \vec{J}_N)}{\partial \vec{J}_k}$$

Element size about 5 nm
up to 500 000 elements

effective field on irregular grids
rigid magnetic moment at the nodes

Applied magnetic field profiles:

- constant reversed field or H(t)
- constant rotational field at 1 Ghz or 10 GHz



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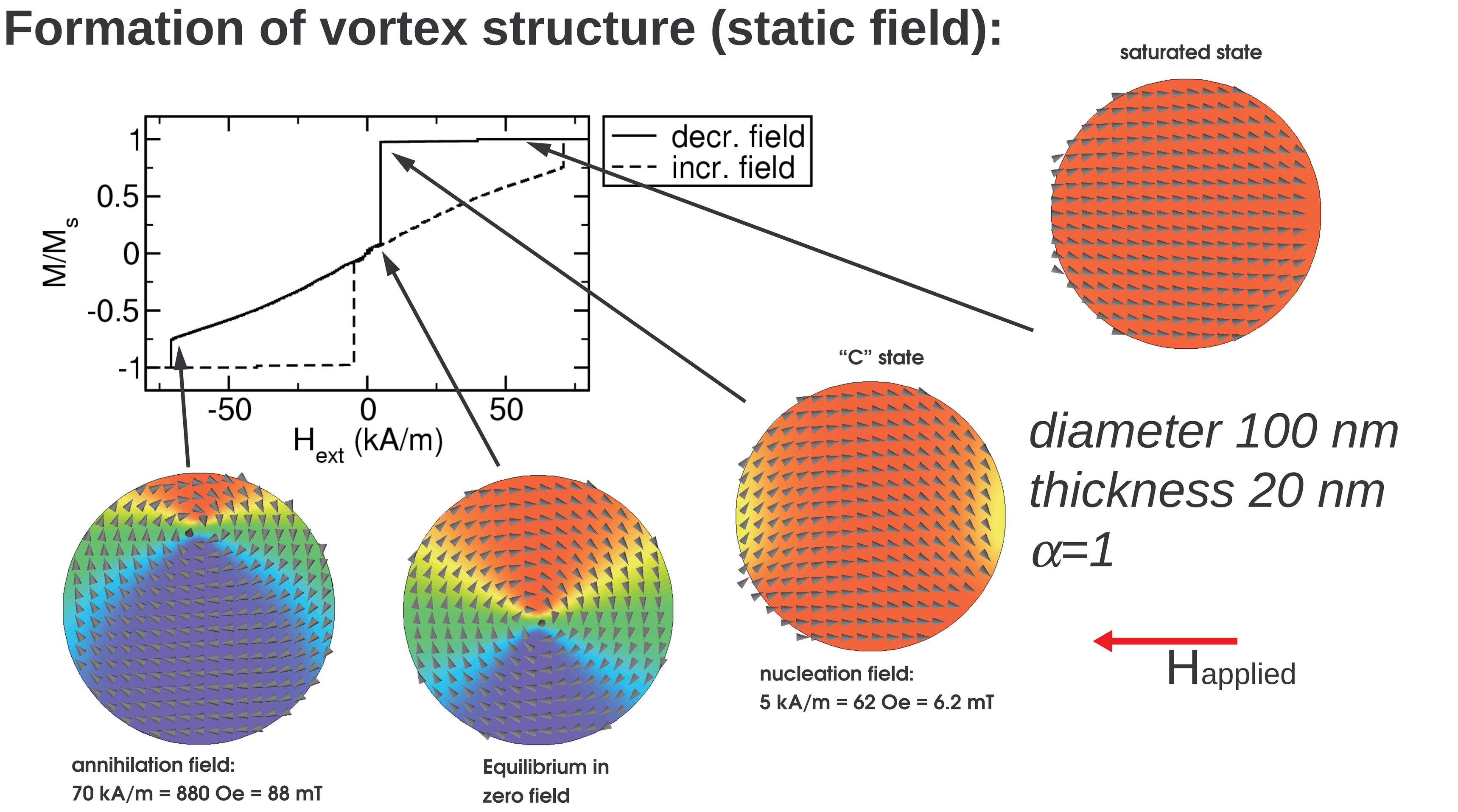
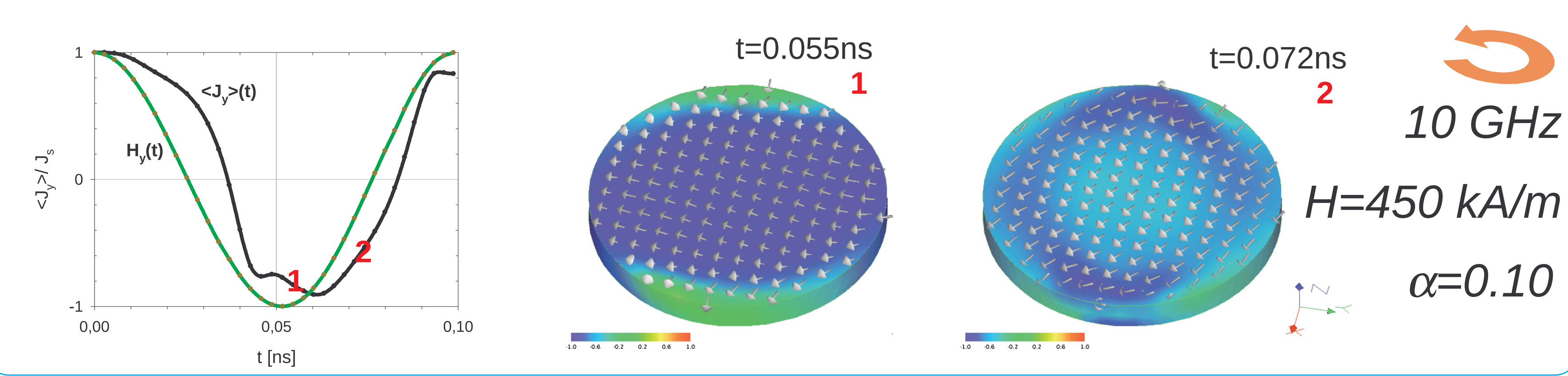
Switching of $Ni_{80}Fe_{20}$ dots

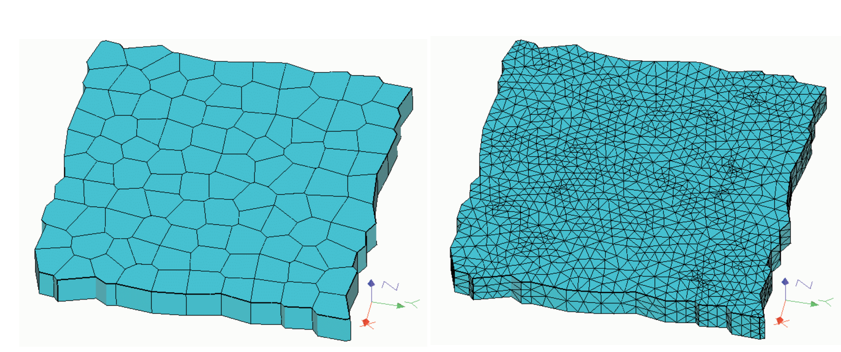
Formation of vortex structure (static field):



Transient magnetisation states during dynamic switching:

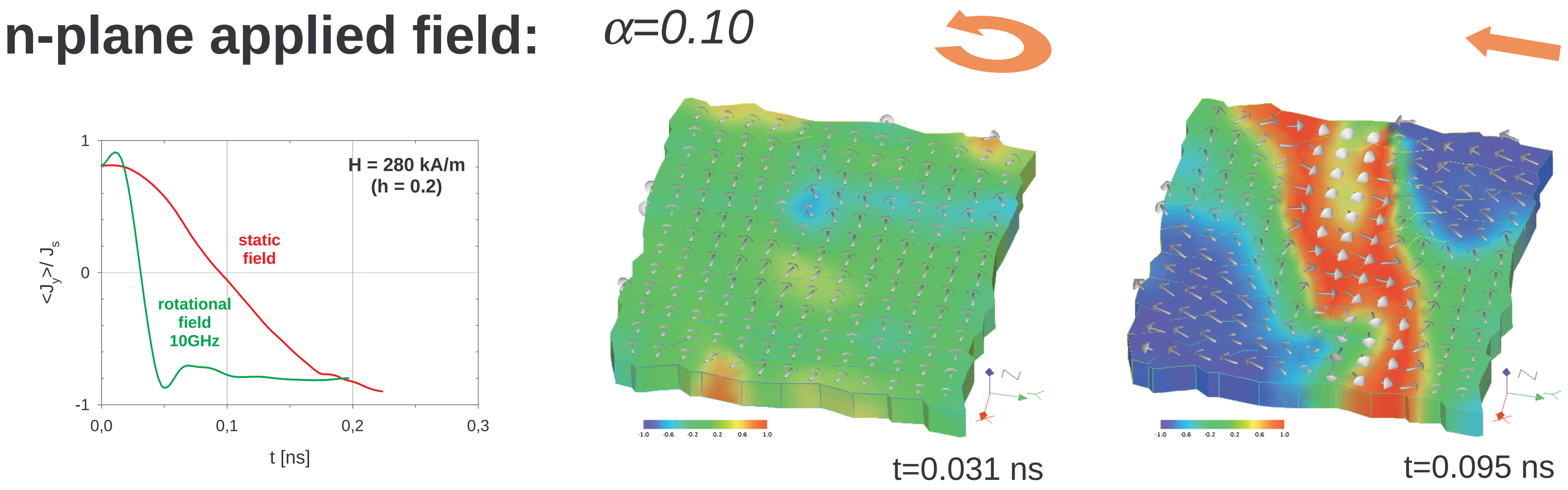


Switching of granular Co-square

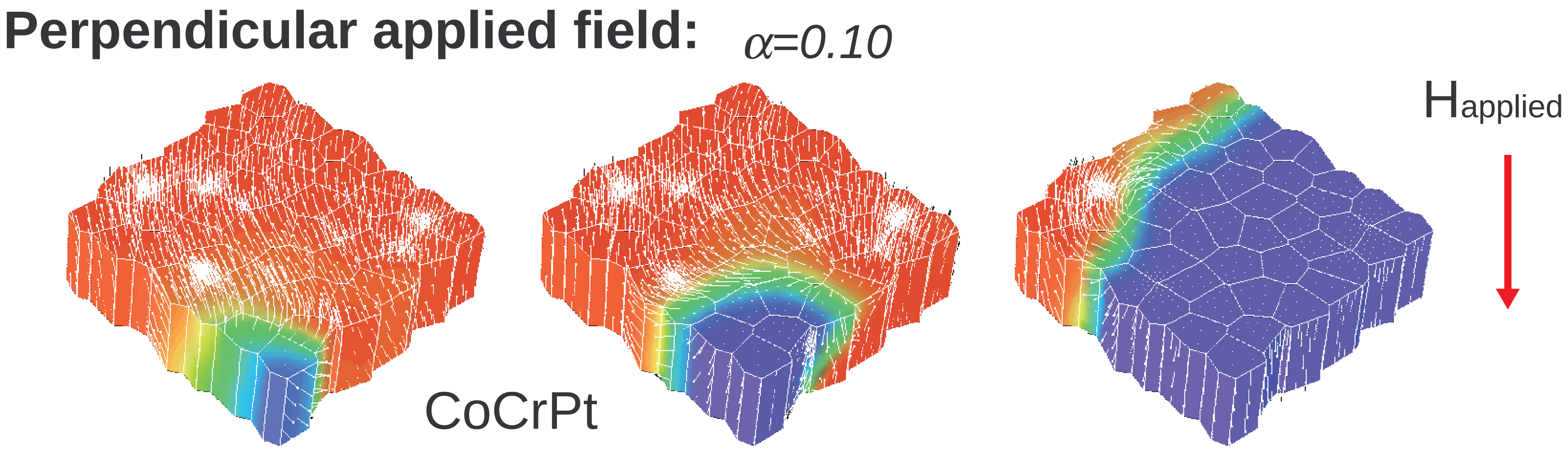


100x100x20 nm³
100 grains
grain diameter 10 nm

In-plane applied field: *α=0.10*



Perpendicular applied field: *α=0.10*



Summary

Micromagnetic simulations of future ultra-high density magnetic recording media up to 500 Gbit/in² reveal details of the magnetisation reversal processes. In nanostructured magnets the switching fields and times are controlled by the geometric shape of the magnets, the intrinsic properties, the orientation, and strength of the applied field and the damping parameter α.

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http://magnet.atp.tuwien.ac.at